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IMAGE PERFORMANCE TRENDING OF THE RAPIDEYE CONSTELLATION AFTER 6 YEARS OF OPERATIONS

- Andreas Brunn, Cody Anderson, Taha Moufid

- RapidEye Introduction and Motivation for Quality Trending
- Calculation of Noise Contents
 - Fully automatic method throughout the full Image dynamic range
 - Noise trends throughout the mission lifetime
- Sensor Sensitivity Trends
- Satellite Health Trends



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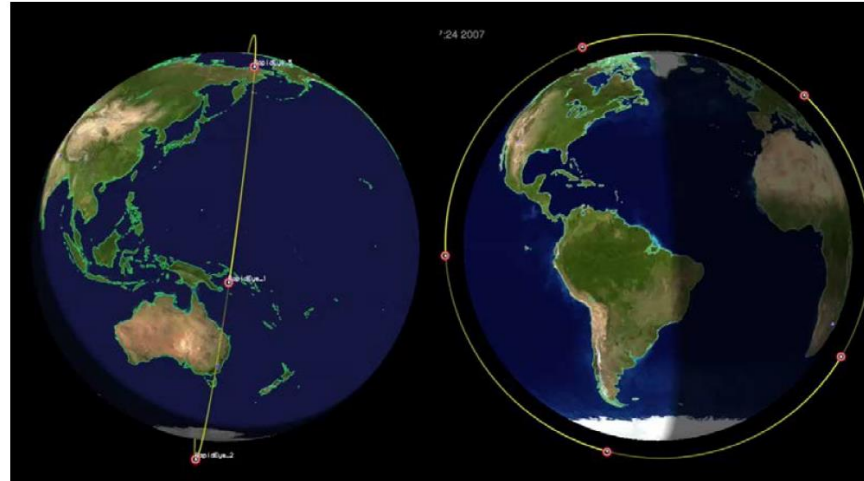
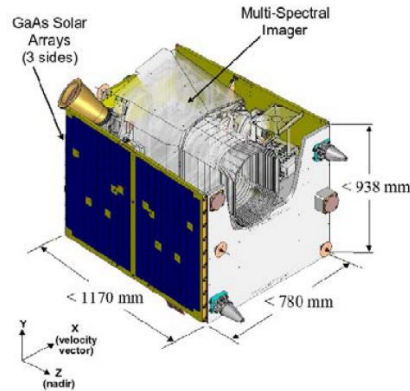
INTRODUCTION AND MOTIVATION FOR QUALITY TRENDING

Space Segment Overview



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- Constellation of 5 small satellites equally phased in sun-synchronous orbits (approx. 630 km altitude)



Motivation

- It is normal and expected that aging of components (like camera, battery, etc.), increased by the harsh environmental conditions in space, is decreasing imaging quality and capacity
- BlackBridge wants to offer its customers always the best possible data quality => this requires a comprehensive knowledge of any image quality change
- To deliver the best quality image products to the customers the data providers need to react on changes as soon as possible



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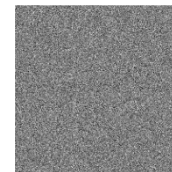
NOISE TRENDING

Detection of Homogeneous Areas

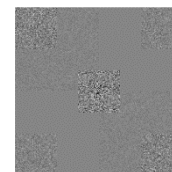


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- Image area is subsetting to small blocks of adjustable size
- Blocks are polluted with poisson noise
- Pearson correlation coefficient between the polluted and un-polluted block is calculated as a measure of homogeneity
- The lower the original block is correlating to its polluted twin, the more homogeneous the block is



Homogeneous Area
=> Low correlation

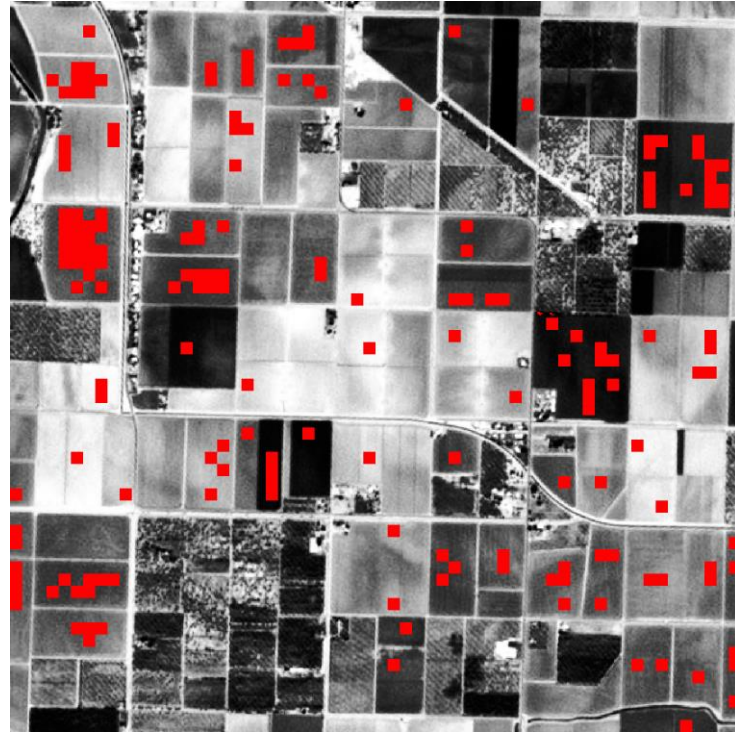


Heterogeneous Area
=> Higher correlation

Detected Homogeneous Areas



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Noise Evaluation

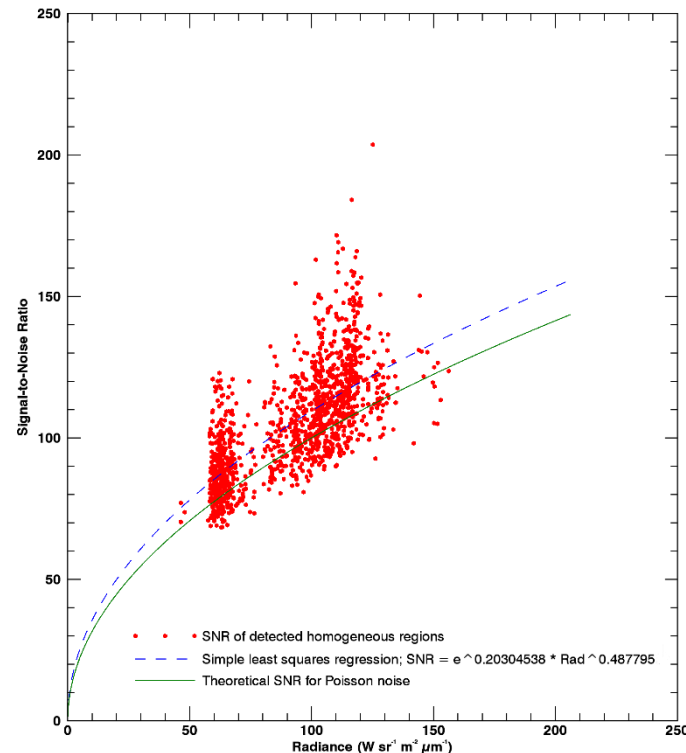


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- All detected homogeneous blocks have different radiance levels

$$NOISE = \frac{Mean(DN)}{STDDEV(DN)}$$

- Noise for each of the blocks is calculated
- Poisson noise is assumed to match the noise levels over the full dynamic range of the response

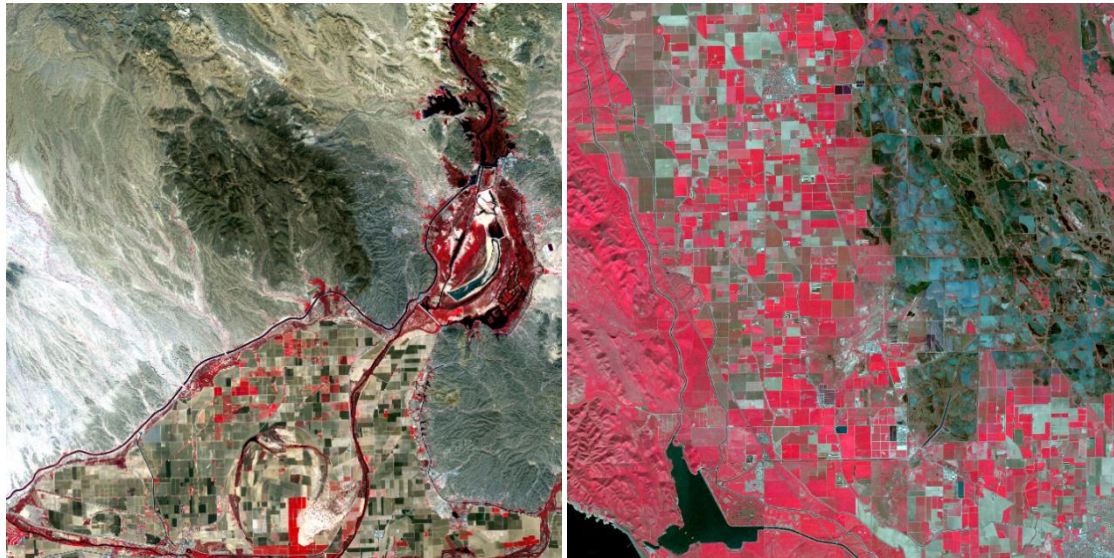


Noise Trend Estimation



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- Two Tile Ids having a frequent occurrence and a high dynamic range have been processed from the archive
- A total of over 400 image products (cloud free, no blackfill) from both tile Ids have been used to trend the noise behaviour of the camera over 6 years



Noise Trend Estimation

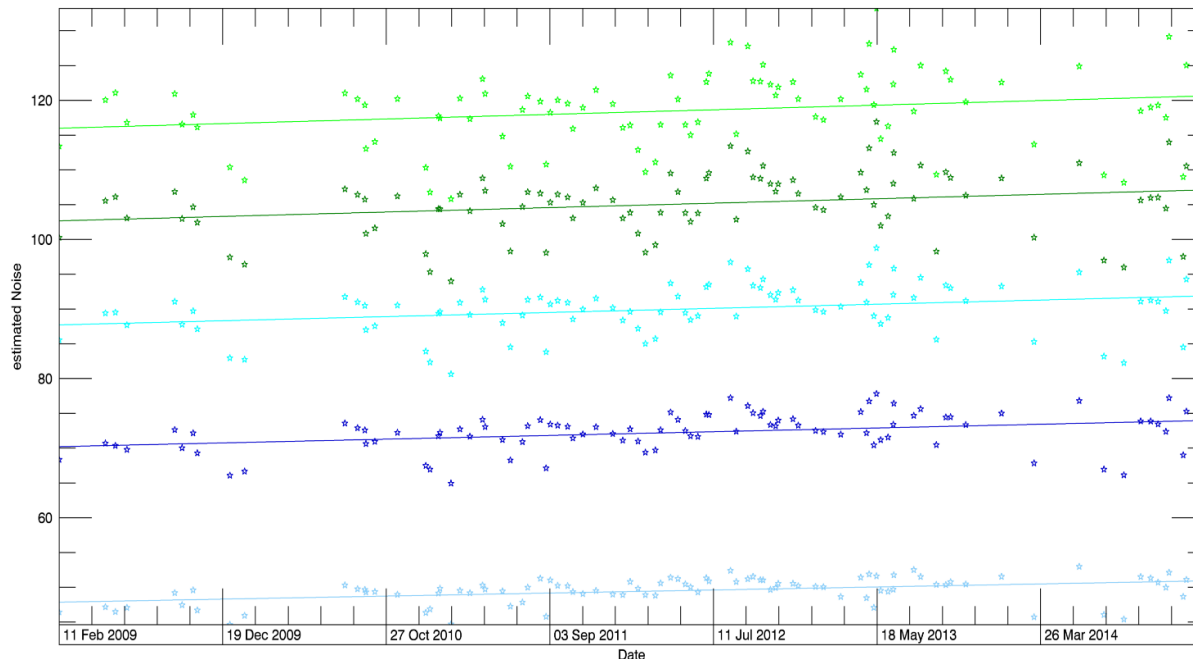


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Noise trends on different
brightness levels

Trendlines over 6
years show very
stable performance

Some fluctuation over
the year due to seasonal
sun angle changes



Noise Trends Over 6 years of Operation



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Very stable image performance with regard to noise

- No band shows clear losses in image performance
- All but 3 bands show clear positive noise trend
- 3 bands are stable within the methods accuracy

	Blue	Green	Red	Red-Edge	NIR
RE1	2.60	3.87	4.61	7.04	4.79
RE2	0.61	-0.69	4.03	4.07	2.67
RE3	4.24	4.01	8.22	8.28	7.47
RE4	0.98	3.57	4.06	6.67	5.65
RE5	3.35	5.52	6.45	5.59	3.54

noise measure on Jan 31, 2015 minus noise measure Feb 01, 2009



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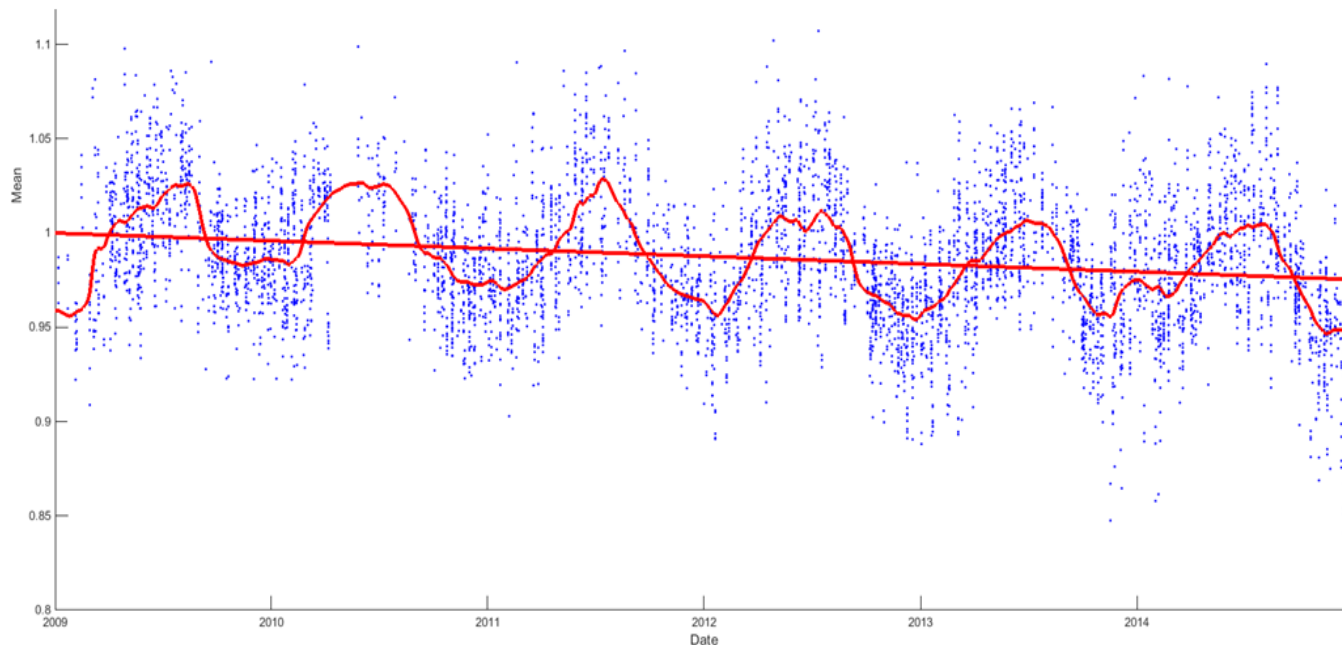
SPECTRAL RESPONSE TRENDING

Response Trending - Methodology



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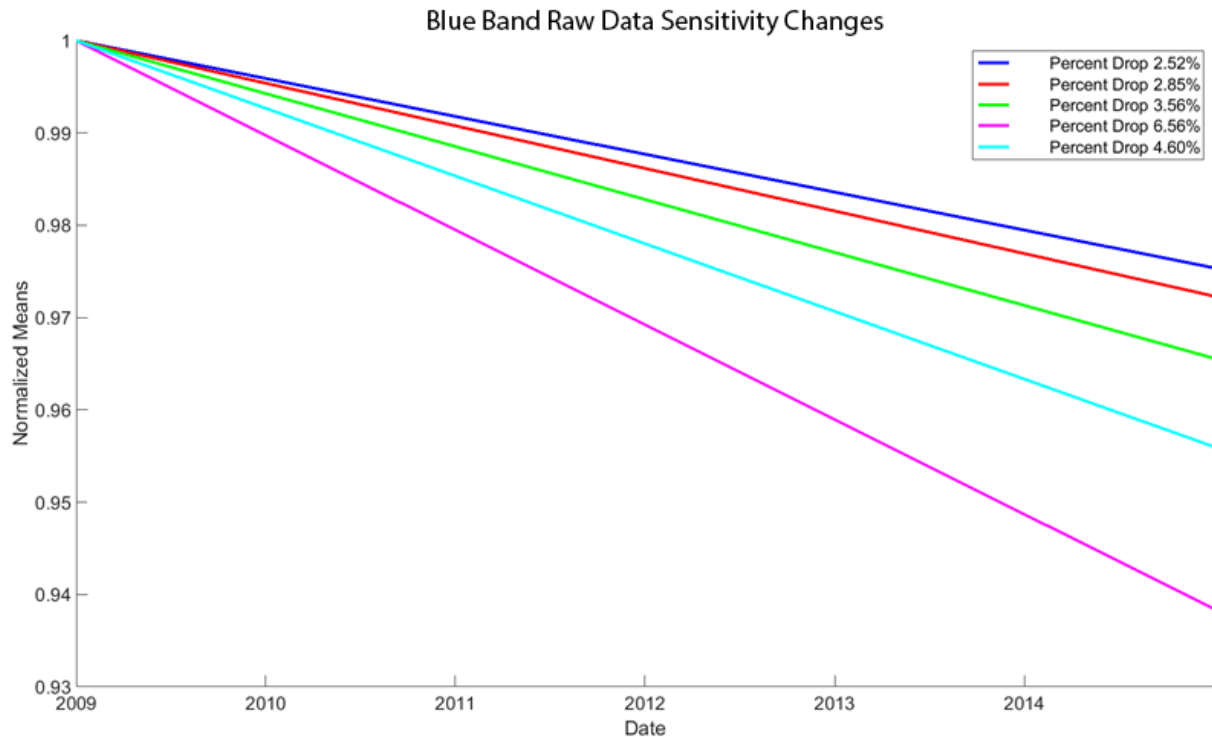
- 26 Sites twice per month
- Over the whole mission life
- Supported by vicarious absolute calibration



Blue Band Trends - Raw Data



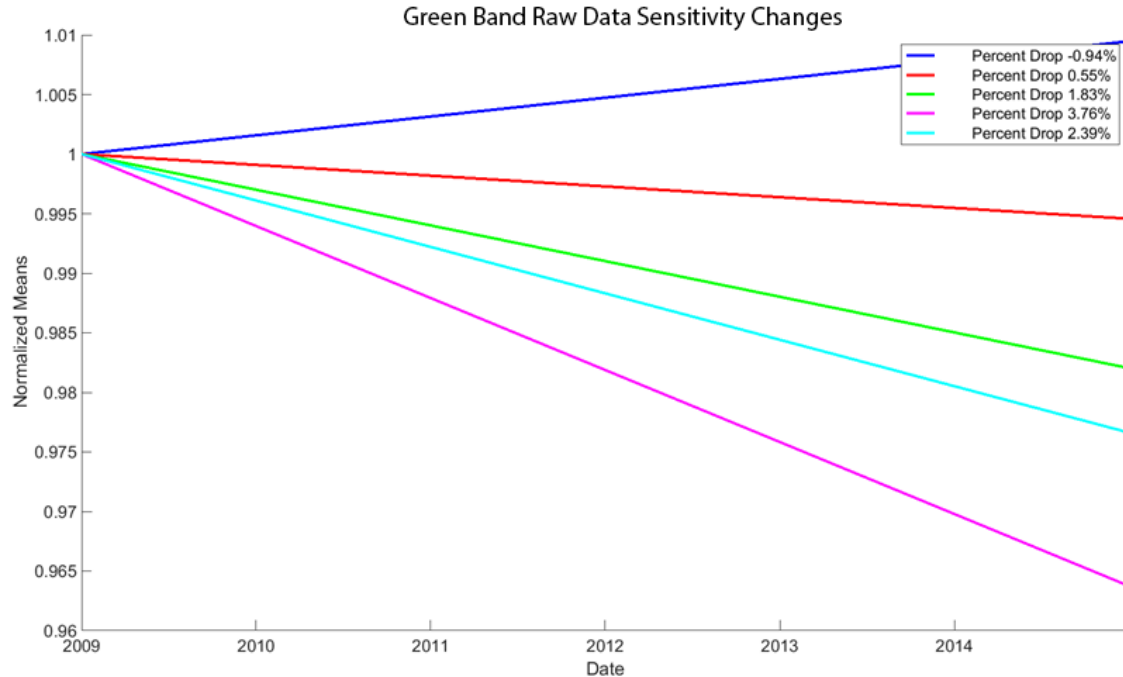
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Green Band Trends - Raw Data



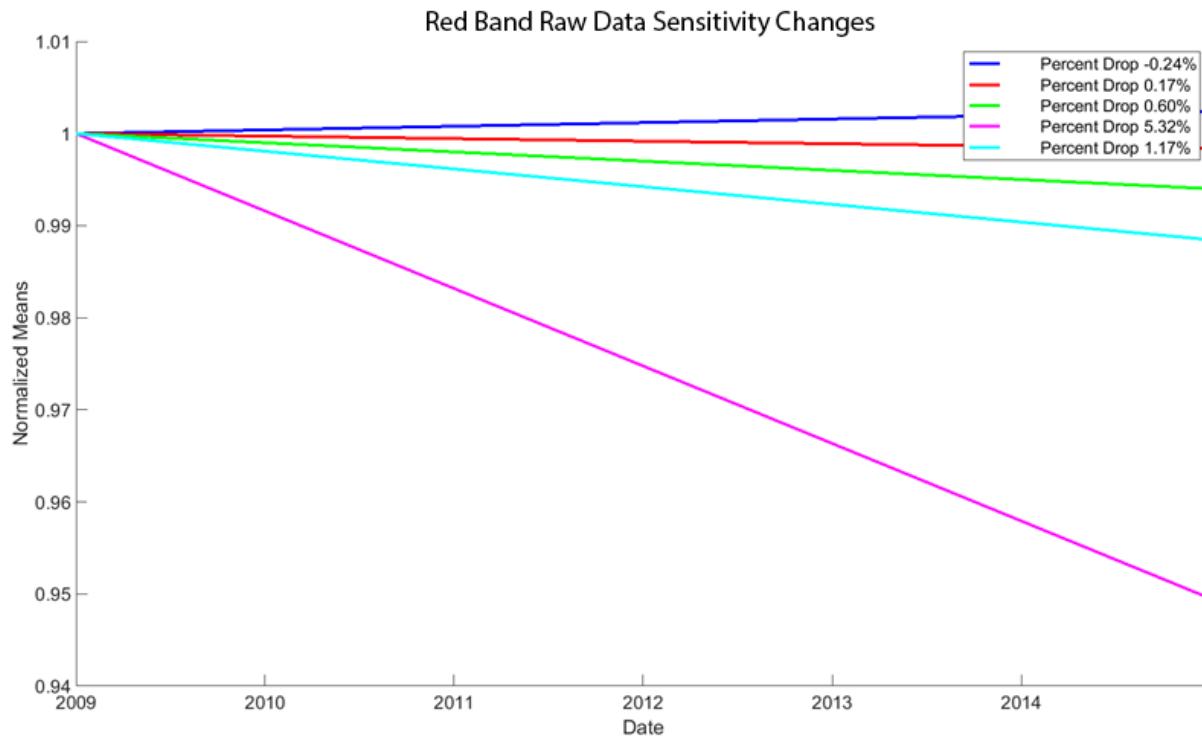
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Red band Trends - Raw Data



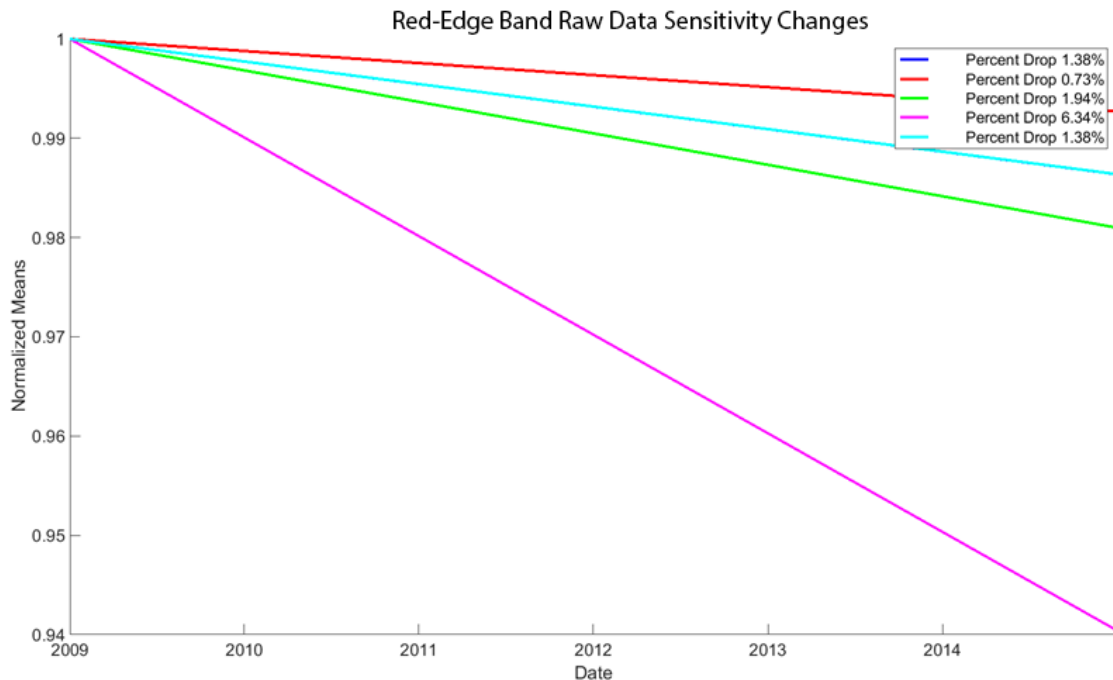
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Red-Edge Band Trends - Raw Data



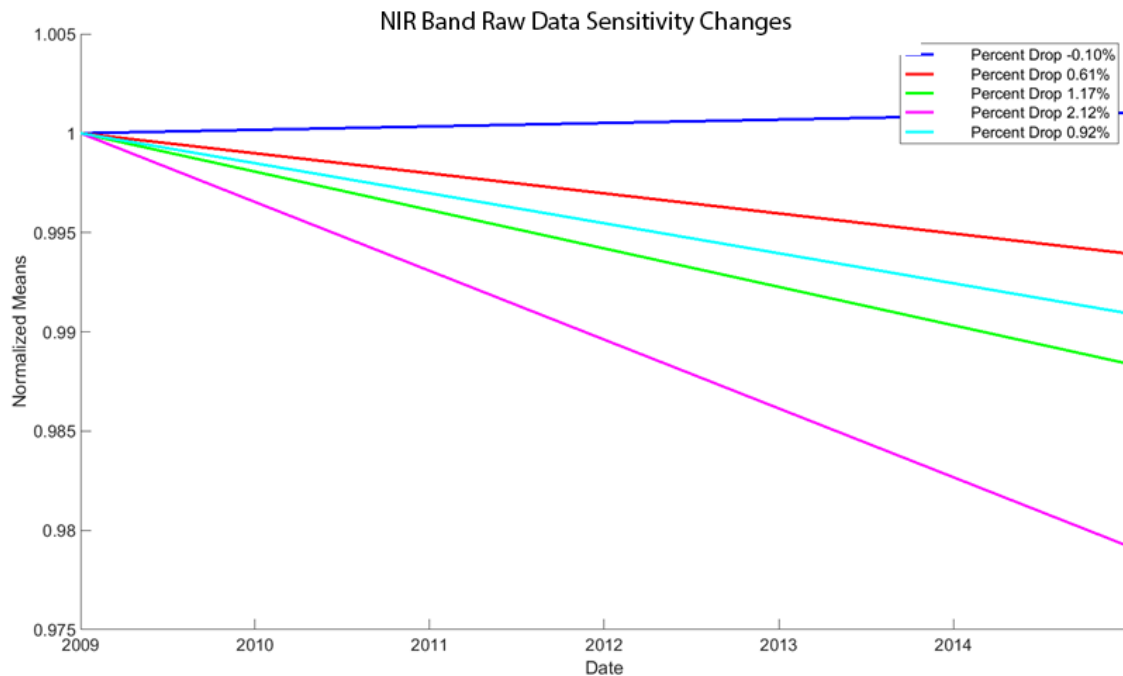
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NIR Band Trends - Raw Data



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Raw Data Trends - Conclusion



- There are small degradation trends in the sensor response of all bands and all spacecraft.
- Such trends are expected and normal for CCD based spacecraft cameras. The measured degradations are smaller than expected.
- All of the shown trends have been corrected in the products which are fully compliant to the specifications.



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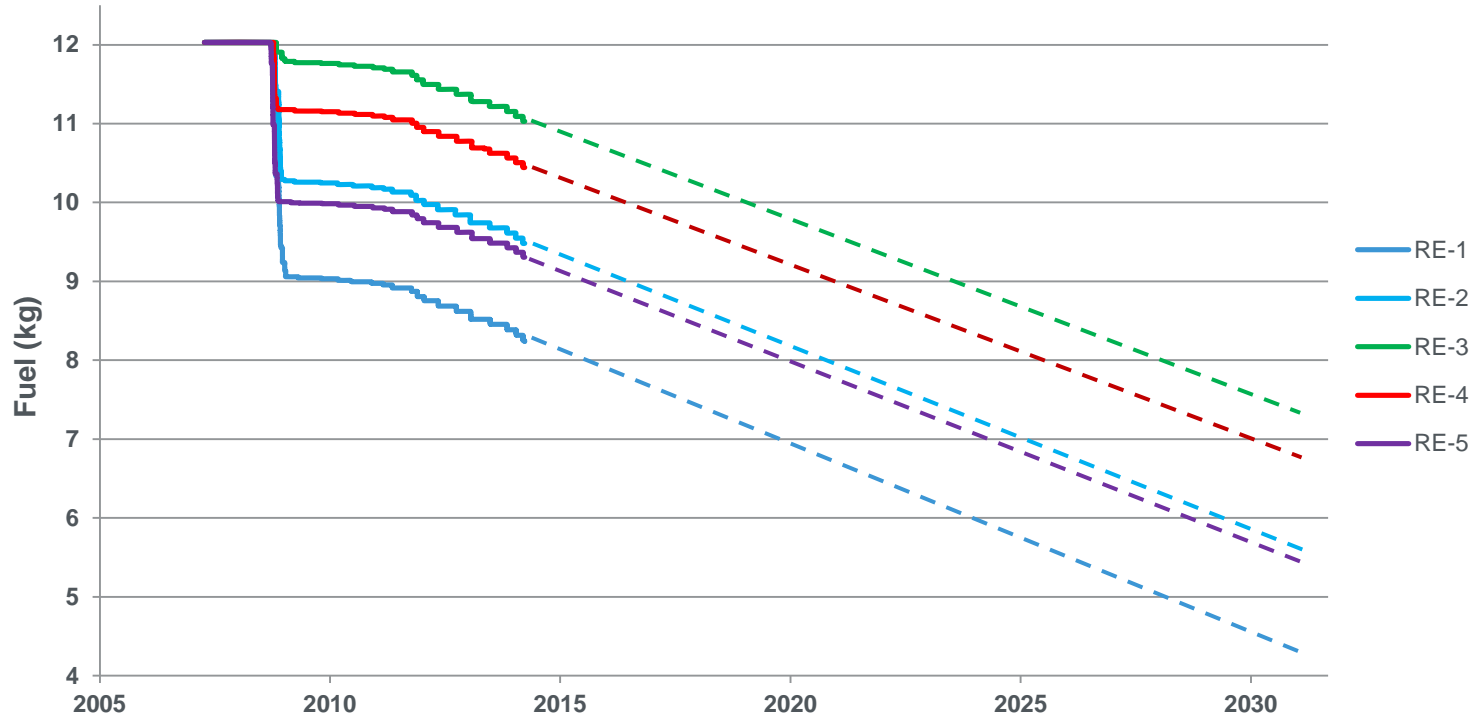
SPACECRAFT HEALTH TRENDS

Info from: Dr. Kam Shahid

Technical Status – Onboard Fuel



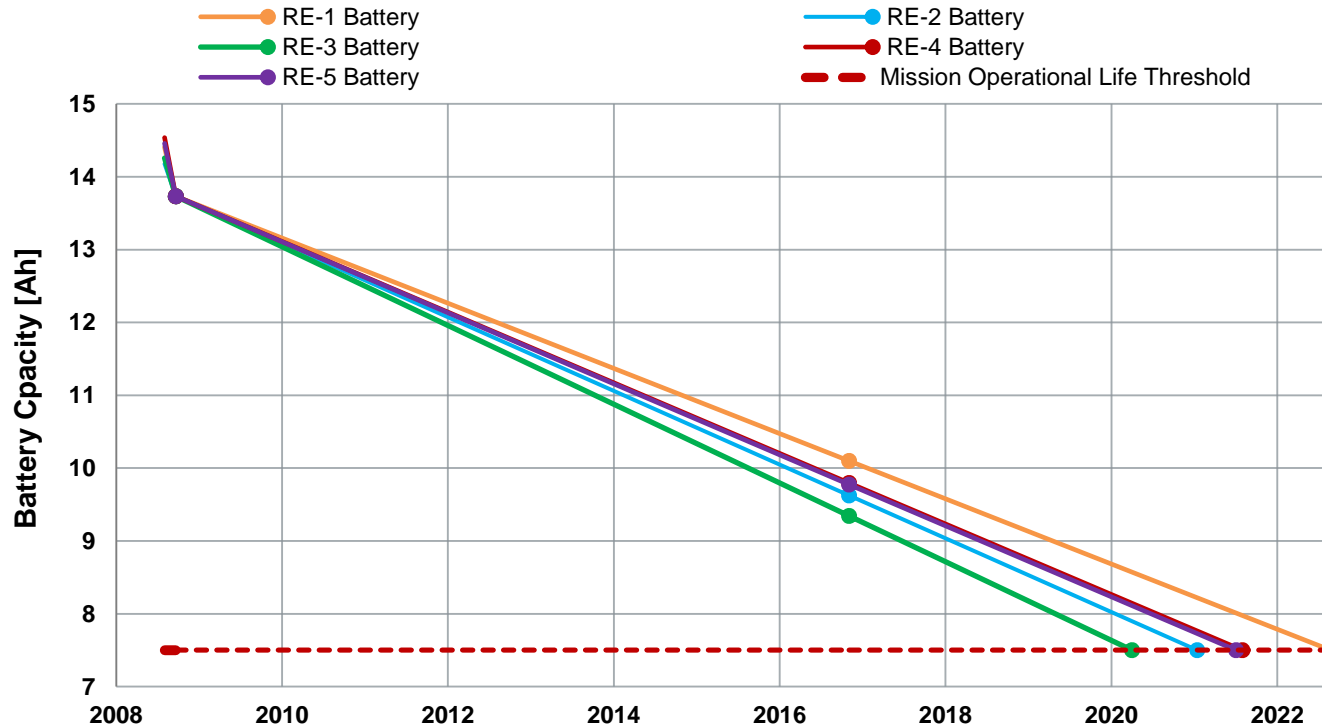
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Technical Status - Battery



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Battery capacity extrapolation. Red line marks the point where the imaging capacity has to be reduced due to power limitations.

Independent 3rd Party Assessment



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- “It is clear that the RE mission operations team has demonstrated both the **expertise** and **creativity** to continue successfully maintaining and operating the RE constellation for the foreseeable future”
- “Since launch, the RE team has significantly upgraded their ground software, moved their operations center, and exchanged downlink antennas **without impacting the operations or performance** of the RE service”
- “Their **responsive operations** are evident by the efficient use of propellant and direct coordination and automation with the ESA Space Operations Center for **ensuring safety of flight**”

Life Expectancy



- It is our assessment that BlackBridge will be able to use the current RapidEye assets to meet its mission performance requirements and continue operating **through 2020**.
Pinnacle Space
- We estimate with a **HIGH probability** that the RapidEye mission can continue **through 2020**.

Conclusion



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- Constellation after 6 years of operations is fully functional and will deliver the full image performance for another 5 or more operational years

BlackBridge in Action

Volcan Villarrica, Chile



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Images collected January 7, 2015 (left) and March 4, 2015 (right)

BlackBridge in Action

Calbuco Volcano, Chile



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Images collected March 4, 2015 (left) and April 24, 2015 (right)



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